Survey of the Fishery Resources in the Fox River Watershed, Alaska, 1985-1986

Mary W. Faurot
and
Douglas E. Palmer

U.S. Fish and Wildlife Service
Kenai Fishery Assistance Office
P.O. Box 1670
Kenai, Alaska 99611

July 1992

Disclaimer

The mention of trade names or commercial products in this report does not constitute endorsement or recommendation for use by the federal government.

The correct citation for this report is:

Faurot, M.W. and D.E. Palmer. 1992. Survey of the fishery resources in the Fox River watershed, Alaska, 1985-1986. U.S. Fish and Wildlife Service, Alaska Fisheries Technical Report Number 18, Kenai, Alaska.

Abstract

The Fox River watershed is located in the southern part of the Kenai National Wildlife Refuge. Fishes inhabiting the watershed were sampled from May through November during 1985 and 1986 using hook and line, gill nets, beach seines, dip nets, and minnow traps. Aerial and ground counts and radiotelemetry surveys of anadromous salmonids were conducted concurrently with fish sampling. Sport fishing use was examined and physical and chemical characteristics of the waters in the watershed were measured.

Eleven fish species were identified in the Fox River watershed including five species of Pacific salmon *Oncorhynchus* spp., Dolly Varden *Salvelinus malma*, eulachon *Thaleichthys pacificus*, threespine stickleback *Gasterosteus aculeatus*, ninespine stickleback *Pungitius pungitius*, coastrange sculpin *Cottus aleuticus*, and slimy sculpin *C. cognatus*. Coho salmon *O. kisutch* were the most abundant and widely distributed salmon species. Adult coho salmon returned to the Fox River watershed starting in August and spawned primarily in Clearwater Slough, Clay Creek, and the mainstem Fox River. Other salmon species returned to the Fox River during July and early August. Pink salmon *O. gorbuscha*, chum salmon *O. keta*, and chinook salmon *O. tshawytscha* spawned primarily in Clearwater Slough and Helicopter Creek. Sockeye salmon *O. nerka* spawned in several clear water tributaries to the Fox River. Escapement estimates for Clearwater Slough and Clay Creek based on spawner counts in 1986 were 3,554 coho salmon, 2,084 sockeye salmon, and 325 chum salmon. The majority of sockeye and chum salmon returned to the Fox River after spending three years in the ocean, whereas coho and pink salmon generally remained in the ocean only one year.

Important rearing areas for juvenile salmonids were Clearwater Slough, Clay, and Windy creeks. Catches of juvenile coho salmon in minnow traps were highest at Clearwater Slough and Windy Creek. Highest catches of juvenile Dolly Varden were at Windy and Clay creeks. Juvenile sockeye salmon were captured primarily with beach seines in protected backwater habitats at Clearwater Slough and Clay Creek. No juvenile pink, chum, or chinook salmon were captured. Juvenile sockeye salmon captured were age 0.0 and coho salmon were age 0.0, 1.0, and 2.0.

Sport fishing use was heaviest during the coho salmon run. Some illegal harvest was observed indicating a need for more effective dissemination of information and greater vigilance in law enforcement.

Table of Contents

List of Tables

List of Figures

List of Appendices

Introduction

Salmon resources are important to subsistence, commercial, and recreational fisheries in Kachemak Bay. The Fox River, a major river originating on the Kenai National Wildlife Refuge and entering Kachemak Bay (Figure 1), contributes to these fisheries, however, little is known about the life histories of either anadromous or resident fishes in this watershed.

The Alaska Department of Fish and Game (Department) has included the Fox River watershed in some of their surveys. Results of a coho salmon *Oncorhynchus kisutch* tagging study in Kachemak Bay showed that nine of 233 fish tagged were recovered in the Fox River (Alaska Department of Fish and Game 1971). Weekly aerial counts were conducted at Clearwater Slough (Figure 2) during August and September in 1981 and 1982 in an attempt to establish an escapement index for coho salmon in Kachemak Bay (Alaska Department of Fish and Game 1982a). These aerial counts and additional counts in 1960, 1969, 1976-1979, and 1983-1985 (Alaska Department of Fish and Game 1985a) identified the following numbers of fish present in Clearwater Slough and other clear water tributaries in the Fox River watershed: (1) "few" to 1,050 sockeye salmon *O. nerka* in June and July; (2) 50-750 pink salmon *O. gorbuscha* in August; (3) 1,500-2,500 Dolly Varden *Salvelinus malma* during August and September; and, (4) up to 1,800 coho salmon during August and September. Clearwater Slough remains the escapement index stream for the subsistence set gill-net fishery in Kachemak Bay which targets coho salmon (Alaska Department of Fish and Game 1985b). Although some information has been collected, the Department continues to recognize a lack of data on coho salmon, particularly regarding escapement in Kachemak Bay tributaries.

Development of a hydroelectric facility at nearby Bradley Lake (Federal Energy Regulatory Commission 1985) could impact the fisheries and aquatic habitat of the Fox River watershed. The Bradley River flows into Kachemak Bay adjacent to the Fox River mouth (Figure 2) and any alteration of the pattern of freshwater inflow here could disrupt salmon migrations within the estuary, ultimately affecting anadromous fish bound for the Fox River. Construction of the facility has enhanced public access and may subject the fishery to long-term increased harvest. A 99-m wide powerline transmission corridor linking a Homer Electric Association powerline to the hydroelectric powerhouse crosses the Fox River Valley (Figure 2). Maintenance activities associated with the powerline may further enhance public access to the Fox River. This could result in riparian habitat impacts and possible degradation.

An environmental impact statement for the Bradley Lake Project was prepared by the U.S. Army Corps of Engineers, Alaska District (1982a, 1982b) and published by the Federal Energy Regulatory Commission (1985). Limited surveys of water quality, aquatic habitat, stream discharge, and fishery resources were conducted on the Fox River as part of these investigations. Salmon escapement monitoring studies in the Bradley River were initiated in July 1986 by contracted Alaska Power Authority

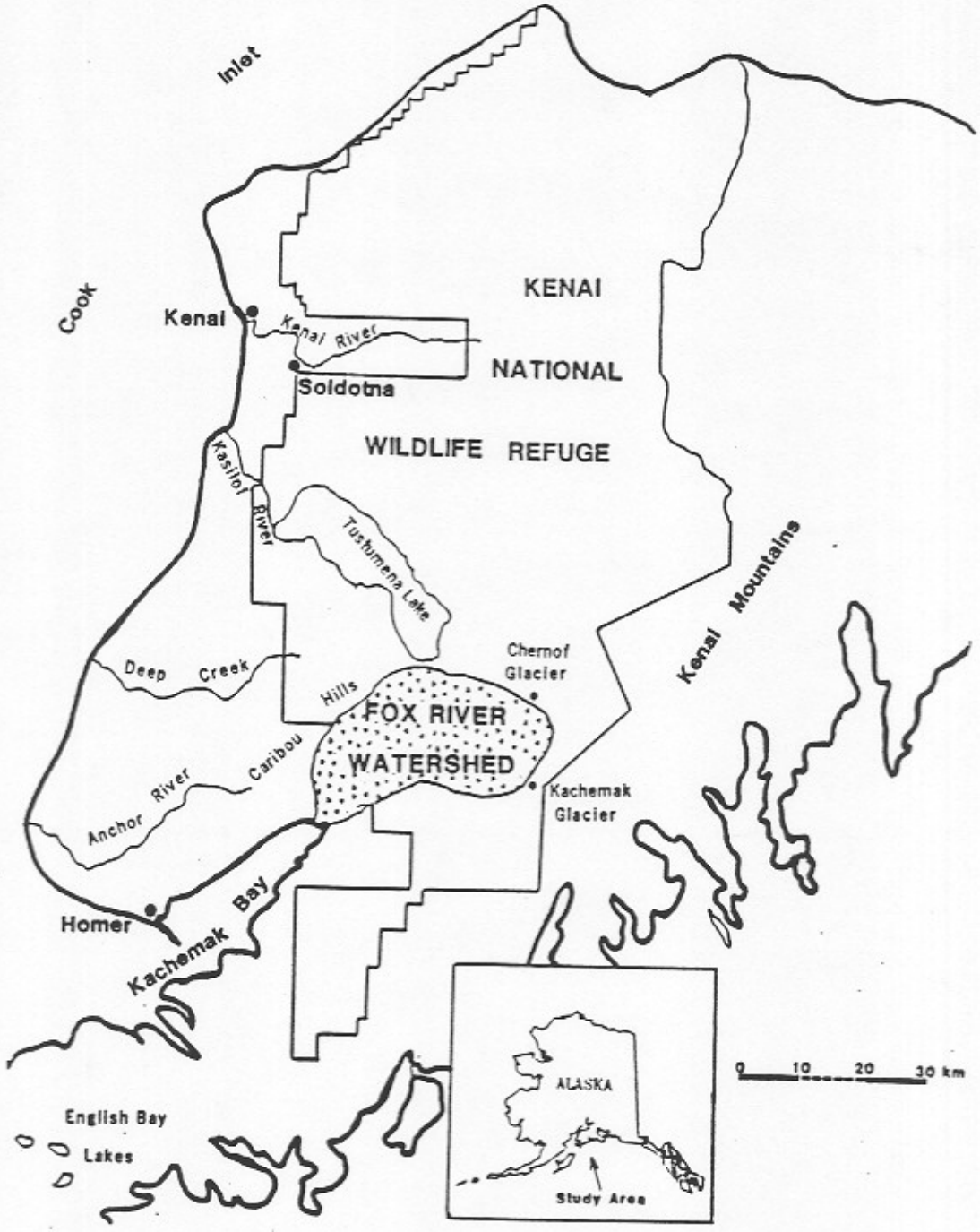

FIGURE 1.—Fox River watershed, Kenai National Wildlife Refuge, Alaska.

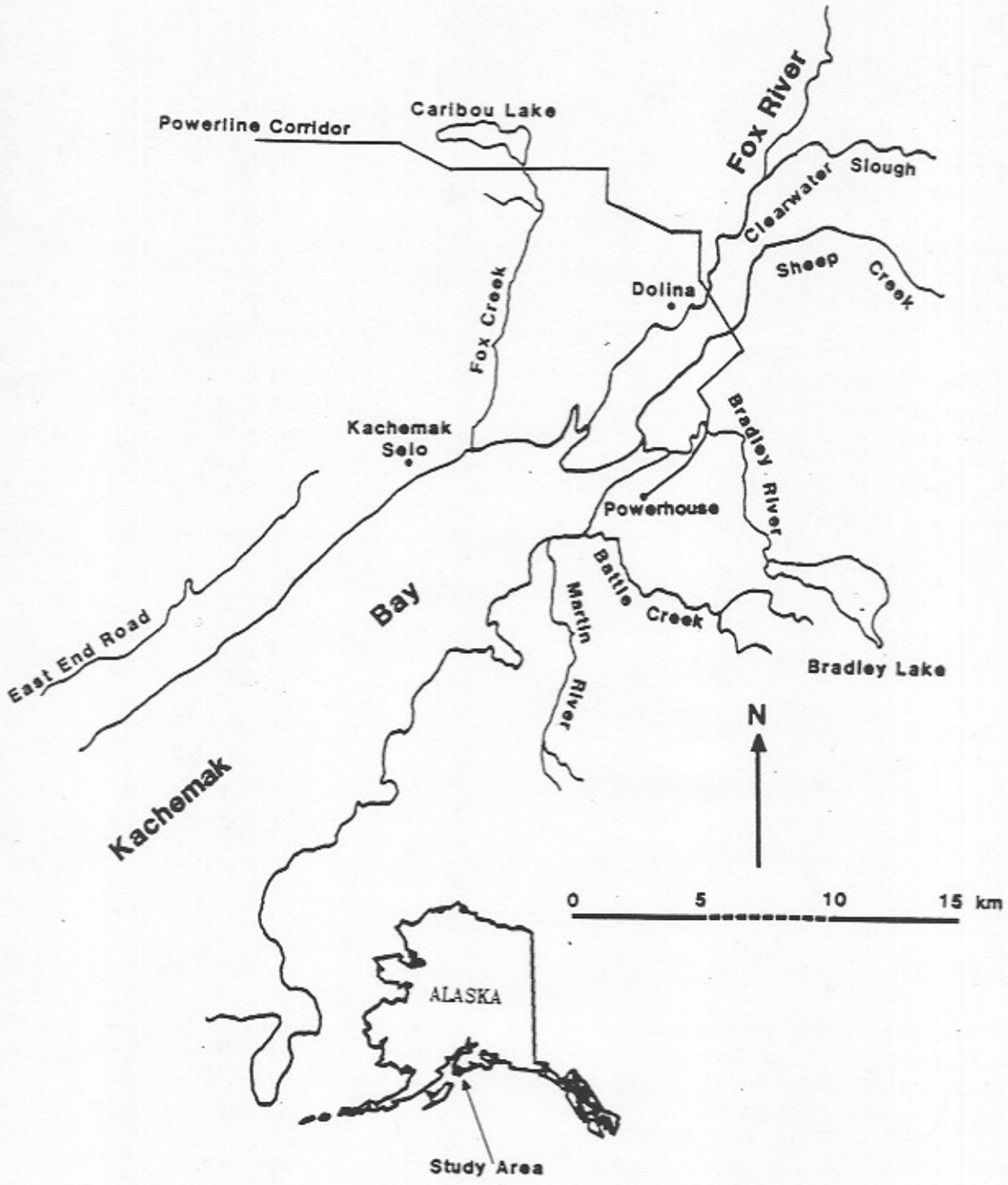

FIGURE 2.—Fox River mouth area, Alaska.

and bedload during the spring, summer, and fall months. Runoff is influenced by headwater glaciers and the Gulf of Alaska maritime climate, and is characterized by peak flows during late summer when glacial melt is rapid and precipitation rates are high.

Several tributaries drain into the Fox River as it descends to Kachemak Bay (Figure 3). Clearwater Slough and Clay Creek, both clear water streams, are the largest tributaries to the Fox River, draining watersheds of 49 km^2 and 59 km^2, respectively. Other smaller streams and lakes in the Fox River drainage do not have official names and were named during the course of this study to simplify identification. Bog stained streams in the Fox River watershed are Windy, Bog, Two Log, and Orange creeks and Clearwater Lake Fork. All other streams in the watershed are clear water streams.

The largest of three lakes in the drainage is Windy Lake (17 hectares), which drains into the upper Fox River and is located at an elevation of 189 m. High Lake (11 hectares) is located at an elevation of 427 m and drains into the upper Fox River by way of Waterfall Creek. Clearwater Lake (12 hectares) is at an elevation of 138 m and drains into Clearwater Slough through Clearwater Lake Fork.

Methods

Field work began in May and continued through early November in both 1985 and 1986. Four primary sampling sites were established at: (1) the mouth of Clearwater Slough; (2) Helicopter Creek; (3) the Fox River upstream of Clearwater Slough; and, (4) the Windy and Clay creek area (Figure 3). Sampling at primary sites was conducted on a weekly or biweekly basis during 2-4 day sampling trips.

Additional sampling was conducted at other locations on a less frequent basis throughout the Fox River watershed. Bluff and Cache creeks were sampled on several occasions. Other locations sampled at least once during the survey include Clearwater Lake Fork, One Bog, Two Bog, Waterfall, Surprise, Two Log, Bog, and Fry creeks. One day sampling trips were made to Windy, High, and Clearwater lakes.

Field Techniques

The distribution and relative abundance of adult salmon, Dolly Varden, and eulachon *Thaleichthys pacificus* were assessed using aerial and ground counts, hook and line, and various types of gill nets (Appendix 1). Aerial and ground counts were conducted throughout the sample period on Clearwater Slough, Helicopter, Cache, Bluff, Windy, and Clay creeks. Set gill nets were fished for 4-12 hours depending on location and fish density. Drift gill nets were stretched across the stream channel, drifted downstream, and retrieved as soon as a fish was caught. Eulachon were sampled in the lower Fox River during 1985 using a 5 cm stretch mesh, 1.8 m deep gill net hung from a 6.1 m bar. The net

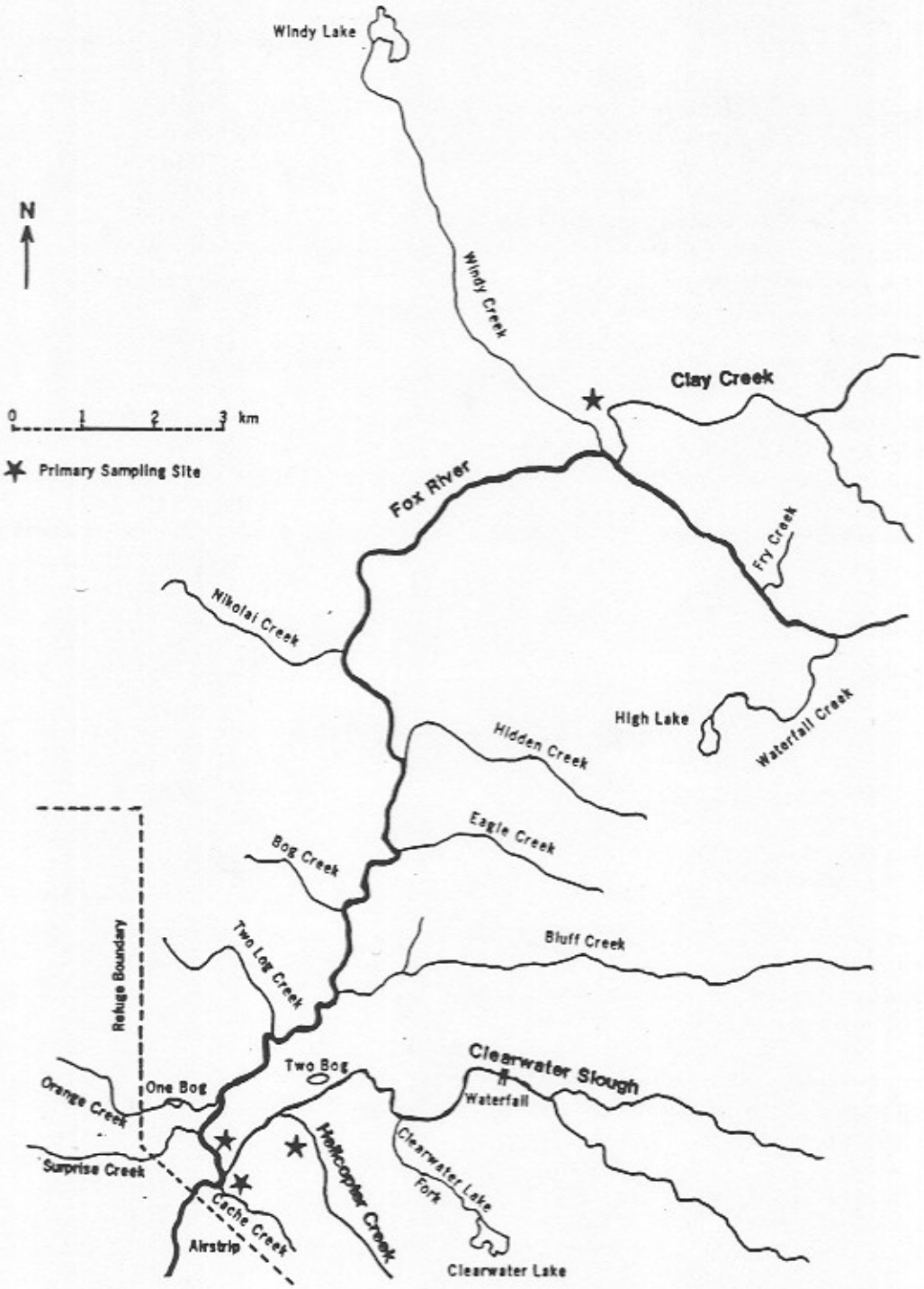

FIGURE 3.—Sampling locations in the Fox River watershed, Alaska, 1985-1986.

was deployed from a boat and drifted through the water column in a manner similar to the drift gill nets.

Efforts were made to measure length and weight and to collect scales or otoliths from at least 50 adults of each anadromous species each year. Age, length, and weight sampling was conducted only at the primary sampling sites. Mideye to fork length for adult salmon and fork length for Dolly Varden were measured to the nearest 5 mm. Weights were determined using spring scales graduated to different levels of precision. Generally, fish weights up to 500 g were measured to the nearest 5 g; weights between 500 and 1,000 g were measured to the nearest 10 g; and weights over 1,000 g were measured to the nearest 50 g.

Distribution and relative abundance of juvenile salmonids, sculpin, and stickleback were assessed by sampling with dip nets, beach seines, smolt nets, and minnow traps (Appendix 1). Minnow traps were baited with salmon eggs and fished overnight (12-16 hours) in a number of reaches and habitats. Efforts were made to replicate minnow trap sampling during each survey trip at primary sampling sites. All captured fish were identified and enumerated. Fork lengths were measured to the nearest mm and scales were collected from a randomly selected subsample of juvenile salmonids in each catch. No weight measurements were taken.

Radiotelemetry was used to determine migration patterns and help identify spawning areas of adult salmonids. Fish to be tagged with radio transmitters were captured in drift gill nets or by angling. External radio transmitters were attached to the fish without using anaesthetic to minimize stress (Wedemeyer 1970), and were secured to fish with stainless steel pins (epoxied to the transmitters) through the interneural bones below the dorsal fin. Petersen discs were threaded over the pins on the opposite side of the fish and held in place by twisting the pins against the discs. Each transmitter was tested before and after attachment to ensure proper operation, and fish were released into slow water and allowed to recover before entering areas of higher flow. Weekly or biweekly tracking flights were conducted in fixed-wing aircraft over the Fox River watershed using a Telonics® receiver and H-antennae in 1985, and an Advanced Telemetry Systems® receiver and loop antennae in 1986.

Radio transmitters manufactured by Advanced Telemetry Systems® were placed on 10 sockeye, six pink, four chum *O. keta*, and six coho salmon during 1985, and on 20 coho salmon and four Dolly Varden in 1986. In 1985, fish that were radio tagged were collected at the mouth of Clearwater Slough with the exception of one coho salmon, which was tagged at the mouth of Clay Creek. Two coho salmon and two Dolly Varden were tagged at Clay Creek in 1986, and the remainder were tagged at Clearwater Slough. Specifications for the transmitters are presented in Appendix 2.

Angler counts and interviews were conducted to determine general patterns and the extent of sport fishing use. All anglers encountered during survey trips were interviewed. Total number of anglers, hours of fishing, number of fish caught, and number of fish kept were recorded along with incidental information on residence and mode of access.

Physical and chemical characteristics of surveyed waters were identified using a variety of equipment. Water temperature and pH were measured using a handheld thermometer and Hach® pH test kit (Model 17-F). Water samples were taken back to the laboratory and alkalinity and conductivity were measured using a Hach® titration kit and YSI® Model 33 meter, respectively. Conductivities were corrected to 25°C to facilitate comparisons between stations.

Stream discharge was estimated from measurements taken with a Marsh-McBirney® Model 201D water current meter. Readings were taken at 0.6 of the water column depth from the water surface. The stream width was divided into cells so that no more than ten percent of the stream flow occurred in any cell.

Data Analysis

Species composition, distribution, and abundance.—Aerial and foot survey observations and catches from angling and gill netting were compiled to determine species composition and distribution of adult fishes throughout the watershed.

Peak total counts from aerial and ground surveys and catch per unit effort from lake gill netting were used as indices of relative abundance for adult lake species, Dolly Varden, and pink salmon. Escapement of adult sockeye, chum, and coho salmon in Clearwater Slough and Clay Creek was estimated using the "Factor 5" method (Cousens et al. 1982):

$$R = MD/T;$$

R = total number of spawners utilizing a given stream section;
M = average of several live counts through the spawning period including the peak;
D = length of time (days) fish are present in the stream;
T = average redd life (days) of individual fish after reaching stream section.

A redd life of seven days was assumed for sockeye salmon based on redd life in the Brooks River on the Alaska Peninsula (Hartman 1959). A redd life of 11 days was assumed for coho salmon based on data from Sashin Creek in southeastern Alaska (Crone and Bond 1976). A seven day redd life was assumed for chum salmon based on data from southeastern Alaska (Mattson and Rowland 1963).

Catch per unit effort from minnow traps was used as an index of relative abundance for juvenile fish, stickleback, and sculpin. Catches were compiled by station, species, date, and year, and those relative

abundances compared. Seining, dip netting, and smolt netting data were used only to determine occurrence of small fishes.

Migration patterns and spawning areas.—Migration patterns of adult salmonids within the Fox River system were monitored with weekly or biweekly aerial radiotelemetry surveys and with ground surveys and sampling at primary sites. Species were considered to be "within" the system when first collected in the Clearwater Slough area. Radiotelemetry and ground observations provided information on movement upstream and into tributaries. Specific runs were considered over when no more fish of a given species were observed during ground surveys and sampling, or when all radiotelemetry observations for a species were repeated in the same location for over three weeks.

Spawning areas of salmon were identified by analyzing radiotelemetry, aerial, and ground survey data. An area was identified as a spawning area if fish were observed exhibiting spawning behavior in a stream reach. Spawning areas for radio-tagged fish were defined as those areas where two or more consecutive, repeated radiotelemetry locations were observed towards the end of an upstream migration.

Rearing areas.—Juvenile fish rearing areas were identified by analyzing catches of juveniles in beach seines, dip nets, and minnow traps. Areas with higher catch rates were assumed to be important for rearing.

Age determination.—Ages were determined from scales of adult salmon collected at primary sampling sites. Salmon scales were cleaned, mounted, and pressed onto acetate sheets using a hydraulic press, and aged using a microfiche reader. Ages of randomly subsampled scales were verified by an independent second reading. Salmon age designation followed the European Method, where the initial numeral indicates the number of winters of freshwater life and the second indicates the number of winters of saltwater life (Koo 1962).

Ages of juvenile coho and sockeye salmon were determined through length frequency analysis and scale analysis of randomly subsampled fish from minnow traps, beach seines, gill nets, and dip nets. Scale analysis and age designation followed methods used for adults. Length and age analyses were conducted on at least 100 juveniles of each species each year.

Otoliths were used to determine ages for Dolly Varden. Otoliths were aged with a 10-40x dissecting microscope using reflected light and techniques described by Jearld (1983) and Heiser (1966). Ages of Dolly Varden were expressed as numerals corresponding to the actual number of hyaline rings or dark bands (winter checks) on the otoliths. Fish were considered to be in age group 0 until the first hyaline ring was observed. Each progressive age group was considered equal to the number of hyaline rings present on the otolith.

Sport fishing use.—Catch rates of sockeye and coho salmon (number of fish caught per hour) were estimated by dividing the number of fish caught by the number of hours spent fishing in a day for all interviewed anglers.

Physical and chemical characteristics.—Stream discharge was calculated at various locations using

$$Q=\sum_{i=1}^{k} wxdxv;$$

Q = discharge (ft^3/s);
k = number of cells;
w = width of cell (ft);
d = mean depth (ft) of cell;
v = mean velocity (ft/s) of cell.

Stream discharges were later converted to metric measures and reported as cubic meters per second (m^3/s).

Water chemistry and stream discharge were measured during each survey trip at primary sampling sites to delineate seasonal fluctuations. Means and ranges were calculated from repeated readings at each location to facilitate relative comparisons within the drainage.

Results

Eleven fish species were captured in the Fox River watershed during 1985 and 1986 (Table 1). Anadromous species included eulachon, Dolly Varden, sockeye, pink, chum, chinook *O. tshawytscha*, and coho salmon. Resident species collected were ninespine stickleback *Pungitius pungitius*, coastrange sculpin *Cottus aleuticus*, and slimy sculpin *C. cognatus*. Both anadromous and freshwater populations of threespine stickleback *Gasterosteus aculeatus* were identified. No fish were found in High or Clearwater lakes.

Sockeye Salmon

Sockeye salmon adults were found at most sampling locations in the Fox River watershed (Table 1). Adult sockeye salmon were first observed in Clearwater Slough during late June in 1985 and 1986, and were present until late August - early September (Figure 4). Primary spawning areas were located in Clearwater Slough and Clay Creek with peak spawning counts observed at these locations during late July (Table 2). All radio-tagged sockeye salmon (N=10) spawned in upper Clearwater Slough below an impassable waterfall. Although most spawning occurred in either Clearwater Slough or Clay Creek, a few spawning individuals were also observed in Bluff, Helicopter, Cache, and Waterfall creeks.

TABLE 1.—Occurrence (X) of species and spawning use (S) at various locations in the Fox River watershed, Alaska, 1985-1986.

Species	Lower Fox River[a]	Cache Creek	Clearwater Slough	Helicopter Creek	Bluff Creek	Upper Fox River[b]	Clay Creek	Windy Creek	Windy Lake
Sockeye salmon	X	XS	XS	XS	XS	X	XS	X	
Pink salmon	X	X	XS	XS					
Chum salmon	X	X	X	XS	X		X		
Chinook salmon	X		XS	XS					
Coho salmon	X	X	XS	XS	X	XS	XS	XS	X
Dolly Varden	X	X	XS	XS	X	X	XS	X	
Eulachon	X								
Threespine stickleback	X		XS	X					X
Ninespine stickleback	X		X				X		
Coastrange sculpin	X	X	X	X		X	X	X	
Slimy sculpin	X	X	X				X	X	

[a] Mouth of Fox River upstream to Clearwater Slough.
[b] Clearwater Slough upstream to Clay Creek.

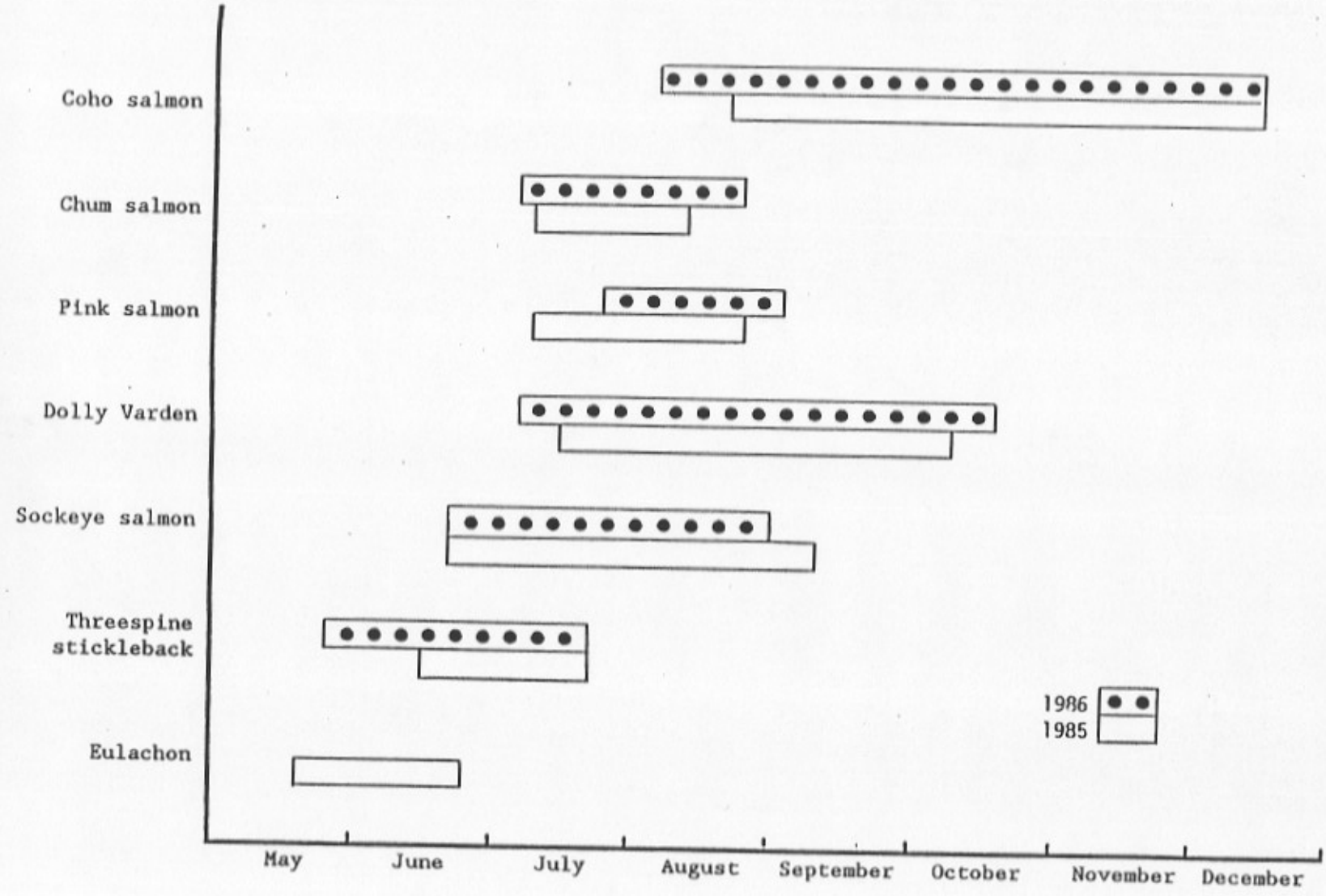

FIGURE 4.—Run timing of anadromous fishes in the Fox River watershed, Alaska, 1985-1986.

TABLE 2.—Counts of adult salmon and Dolly Varden during ground and aerial surveys on Clearwater Slough (CW) and Clay Creek (CL), Fox River watershed, Alaska, 1985-1986.

Date	Sockeye		Pink	Chum	Coho		Dolly Varden	
	CW	CL	CW	CW	CW	CL	CW	CL
				1985				
6/27	50							
7/2	250							
7/25[a]	400		200	30				
8/23		25						
8/28					75			
9/5[a]					250	15		750
9/11[a]	15				360	265	370	2000
9/21[a]					610	250	675	1000
10/3					250			
				1986				
6/25	30							
7/10	215	100		60				30
7/15		97						
7/21		457						
7/27[a]	250			70				
8/5	207		2	66			500	
8/12[a]	10	8			80			
8/20	16		12	31	256		1603	
8/29[a]	6		35	8				
9/4					610	150	990	300
9/24					720	223	900	100
10/1					766	100	954	
10/28					250		50	
11/17[a]					90			

[a] Aerial survey.

Spawning escapement estimates of sockeye salmon in Clearwater Slough and Clay Creek were similar (Table 3). Escapement estimates in Clearwater Slough during 1985 and 1986 were 1,098 and 1,056 fish, respectively. The 1986 spawning escapement in Clay Creek was estimated at 1,028 sockeye salmon. No escapement estimate was made for Clay Creek in 1985.

Four age groups of adult sockeye salmon were identified in the Fox River watershed (Table 4). All age groups (1.2, 1.3, 2.2, and 2.3) were represented in samples collected from Clearwater Slough and Clay Creek, however, age group 1.3 was dominant. Fish from age group 1.3 were generally longer and heavier than those of all other age groups, averaging 550 mm and 2,875 g in 1985, and 563 mm and 2,942 g in 1986.

Most juvenile sockeye salmon were captured with beach seines and dip nets in protected backwater areas of Clearwater Slough and Clay Creek (Table 5). All juvenile sockeye salmon captured were age 0.0 based on a scale analysis of subsampled fish (N=43 for 1985, N=20 for 1986). Juveniles collected in 1985 tended to be larger (mean fork length=51 mm, range=34-66 mm, N=73) than those collected in 1986 (mean fork length=37 mm, range=27-74 mm, N=119).

Pink Salmon

The distribution of pink salmon in the Fox River extended only as far upstream as Clearwater Slough (Table 1). Adult pink salmon arrived at Clearwater Slough during July and remained until late August both years (Figure 4). Spawning was observed in both Clearwater Slough and Helicopter Creek and all six of the radio-tagged fish spawned in Clearwater Slough. Spawning escapement could not be estimated because high turbidity prevented accurate repeat counts of adult pink salmon. However, peak counts of 200 fish in 1985 and 35 fish in 1986 suggest that the run is stronger during odd-numbered years (Table 2).

Age determinations made for pink salmon adults indicated that all fish were age 0.1 (Table 4). Fish from this age group averaged 465 mm and 1,595 g in 1985, and 437 mm and 1,426 g in 1986.

Clearwater Slough was sampled with a smolt net during late May in 1986 in an attempt to determine size and outmigration characteristics of juvenile pink salmon, but no fish were captured.

Chum Salmon

Although adult chum salmon were observed as far upstream as Bluff and Clay creeks, most were found in Clearwater Slough and Helicopter Creek (Table 1). Chum salmon were first observed at Clearwater Slough in early July and remained in the system until mid- to late August both years (Figure 4). Spawning occurred throughout the entire period with the majority, including the four radio-tagged fish, spawning in Helicopter Creek. Peak counts of chum salmon in the Clearwater Slough/Helicopter Creek area were 30 in 1985 and 70 in 1986 (Table 2).

TABLE 3.—Escapement estimates of salmon in Clearwater Slough and Clay Creek using the "Factor 5" method (Cousens et al. 1982), Fox River watershed, Alaska, 1985-1986.

Location and species	Number of live counts	M[a]	D[b]	T[c]	Spawning escapement
		1985			
Clearwater Slough					
Sockeye	3	233	33	7	1,098
Coho	4	368	60	11	2,007
Clay Creek					
Coho	2	258	50	11	1,173
		1986			
Clearwater Slough					
Sockeye	3	224	33	7	1,056
Chum	4	57	40	7	325
Coho	5	520	60	11	2,836
Clay Creek					
Sockeye	3	218	33	7	1,028
Coho	3	158	50	11	718

[a] M = average of several live counts through the spawning period including the peak.
[b] D = length of time (days) live fish were present in the stream.
[c] T = average redd life (days) of individual fish after reaching the stream section. Average redd life data obtained from Hartman (1959), Crone and Bond (1976), and Mattson and Rowland (1963).

TABLE 4.—Age, length, and weight of adult salmon, Fox River watershed, Alaska, 1985-1986.

Species	Age	Mideye-fork length (mm)			Weight (g)		
		N	Mean	SD	*N*	Mean	SD
			1985				
Sockeye	1.2	5	522	67.3	5	2,694	70.3
	1.3	35	550	42.6	35	2,875	884.4
	2.2	4	483	33.0	4	1,613	337.6
	2.3	8	491	41.8	8	2,015	695.2
Pink	0.1	50	465	44.0	50	1,595	412.4
Chum	0.3	25	571	38.1	25	2,822	524.5
	0.4	5	558	26.6	5	2,600	418.3
Coho	2.1	43	604	46.1	43	3,617	939.5
	3.1	20	618	47.2	20	3,990	972.3
			1986				
Sockeye	1.2	8	533	43.5	8	2,763	446.2
	1.3	35	563	46.4	35	2,942	877.3
	2.2	2	563	31.8	2	2,725	618.7
	2.3	2	543	3.5	2	2,675	106.1
Pink	0.1	9	437	35.5	8	1,426	364.2
Chum	0.3	5	564	23.0	5	3,240	929.0
	0.4	1	560	-	1	2,800	-
Coho	2.1	99	581	53.1	68	3,247	935.4
	3.1	9	601	53.8	8	3,400	908.3

TABLE 5.—Number of fish collected with beach seines (S) and dip nets (D) at various locations in the Fox River watershed, Alaska, 1985-1986.

Date	Location	Gear	Juvenile						
			Sockeye	Coho	Dolly Varden	Threespine stickleback	Ninespine stickleback	Coastrange sculpin	Slimy sculpin
					1985				
7/17	Cache Creek	D		4					2
8/3	Helicopter Creek	S		7		1			
8/3	Clearwater Slough	S	49	32				2	
8/22	Clay Creek	S	67	4	1				
8/27	Clearwater Slough	S	92	127		3			
9/12	Clay Creek	S		38					
9/12	Windy Creek	S	26	25					
					1986				
5/28	Clearwater Slough	D	37	1		6			
6/24	Clearwater Slough	D	21	2		12	2		
7/8	Clearwater Slough	S		1		1			
7/9	Fox River	S			7		2	6	
7/10	Two Bog	S		1	7	3		7	
7/15	Clay Creek	S			2				
8/5	Two Bog	S	5	39		73			
8/5	Bluff Creek	D		30	1				
8/12	Clearwater Slough	S	11	41		25			
10/8	Clay Creek	S	500	5			2		

Due to the consistent clarity of Helicopter Creek, repeat counts of spawning adults were possible in 1986, and using the "Factor 5" method, a spawning population of 325 chum salmon was estimated (Table 3).

Two age groups of adult chum salmon were identified in the Fox River watershed (Table 4). Fish from age group 0.3 were more common and slightly larger than age 0.4 fish. In 1985, age 0.3 fish averaged 571 mm and 2,822 g compared to 558 mm and 2,600 g for age 0.4 fish.

Like juvenile pink salmon, no outmigrating juvenile chum salmon were captured in Clearwater Slough during late May in 1986.

Chinook Salmon

Only six adult chinook salmon were encountered in the Fox River system. All fish were observed spawning in Clearwater Slough and Helicopter Creek during mid-August in 1985. None of these fish were captured, therefore no biological data were collected. No juvenile chinook salmon were collected during the study.

Coho Salmon

Coho salmon were the most abundant and widely distributed salmon species, occurring in every major clear water tributary (Table 1). Coho salmon were found upstream as far as the headwaters of the Fox River above Waterfall Creek, and were the only salmon species observed in Windy Lake. Coho salmon arrived at Clearwater Slough in late August, 1985, and in early August, 1986 (Figure 4). Fresh fish (bright silver coloration) were encountered until mid-October, and individuals were still alive at freeze-up in November of both years. Spawning activity was observed from early September through November. Fish moved upstream through November, indicating that spawning could have been occurring even later.

Fish tagged with radio transmitters spawned in three tributaries and in the mainstem Fox River. Two of the six coho salmon radio tagged in 1985 spawned in Windy Creek, two spawned in the mainstem Fox River, and two spawned in Helicopter Creek. In 1986, four radio-tagged coho salmon spawned in Clay Creek, three spawned in the mainstem Fox River, and 13 spawned in either Clearwater Slough or Helicopter Creek. Spawning coho salmon were observed in other tributaries as well, but Clearwater Slough (including Helicopter Creek), Clay, and Windy creeks were the most important spawning areas.

The estimated spawning population of coho salmon in Clearwater Slough was almost twice that observed in Clay Creek during 1985 and almost four times that observed in Clay Creek during 1986 (Table 3). Escapement estimates in Clearwater Slough during 1985 and 1986 were 2,007 and 2,836 fish, respectively. The spawning escapement estimated for Clay Creek was 1,173 fish in 1985 and 718 fish in 1986.

Two age groups of adult coho salmon were identified in the Fox River watershed (Table 4). Fish from age group 2.1 were dominant, comprising 83% (*N*=142) of the fish that were aged. Fish from age group 3.1 were slightly larger than age 2.1 fish. In 1985, age 3.1 fish averaged 618 mm and 3,990 g compared to 604 mm and 3,617 g for age 2.1 fish. For a given age, the average length and weight of coho salmon in 1986 were smaller than averages observed in 1985.

Coho salmon captured in Windy Lake did not exhibit any saltwater growth and were considered residuals. Ages of these fish were 2.0 and 3.0 and lengths ranged from 215-317 mm. The majority of coho salmon captured in Windy Lake (90%, *N*=19) were males.

Juvenile coho salmon were captured at all primary sampling locations with the highest minnow trap catch rates occurring in Windy Creek and Clearwater Slough (Table 6). Catch rates greater than five fish per trap night were observed at these locations during 1985 and 1986. Similarly, beach seine catches of juvenile coho salmon were generally higher at Clearwater Slough than at other sampling locations (Table 5).

The greatest amount of minnow trap effort occurred at the lower Fox River primary sampling site. Catches of juvenile coho salmon at this location fluctuated widely but generally increased during late summer and fall in 1986 (Table 7). A similar trend may have occurred in 1985, but was not apparent due to reduced sampling efforts late in the season.

Three age classes of juvenile coho salmon (ages 0.0, 1.0, and 2.0) were captured in the Fox River watershed. Length frequency analysis and age determinations of subsampled fish indicated a clear break in lengths between age 0.0 and age 1.0 fish. Fork lengths for age 0.0 fish ranged from 29-63 mm (*N*=94 in 1985, *N*=147 in 1986) with a mean of 45 mm. Age 1.0 fish ranged from 66-120 mm (*N*=69 in 1985, *N*=191 in 1986) with a mean of 90 mm. Only two age 2.0 coho salmon were encountered outside of Windy Lake. Fork lengths of these fish were 123 and 130 mm.

Dolly Varden

Dolly Varden were found at all sampling locations from early July through mid-October during both years (Figure 4) with the exception of Windy Lake (Table 1). Primary spawning areas were not identified for this species, as few were actually observed spawning. The few that were observed in spawning condition were located in Clay Creek, Clearwater Slough, and Helicopter Creek in early August. The four fish that were radio tagged in 1986 moved down the Fox River in October and presumably on to Kachemak Bay and their wintering areas. Several attempts were made to locate these fish in English Bay lakes south of Kachemak Bay, where it had been suggested that they wintered (Nick Dudiak, Alaska Department of Fish and Game, personal communication), but none were encountered.

TABLE 6.—Catch per unit effort (number of fish per trap night) for various species in minnow traps at sampling locations in the Fox River watershed, Alaska, 1985-1986.

Location	Number of trap nights	Juvenile			Threespine stickleback	Ninespine stickleback	Coastrange sculpin	Slimy sculpin
		Sockeye salmon	Coho salmon	Dolly Varden				
1985								
Lower Fox River	30	0	6.2	9.1	0	0	3.0	0
Clearwater Slough	18	0	6.4	6.9	1.6	0.1	0.5	0
Helicopter Creek	12	0	2.1	6.6	0.3	0	0.5	0
Clay Creek	6	0	2.5	20.3	0	0	0	0.3
Windy Creek	4	0	9.5	27.5	0	0	0.5	0.5
Windy Lake	10	0	3.7	0	30.2	0	0	0
1986								
Lower Fox River	61	0.1	1.4	3.7	0	0.1	1.3	0.3
Clearwater Slough	32	0.8	15.4	6.0	3.2	0.1	0	0.7
Helicopter Creek	6	0.7	1.8	1.2	0	0	0	0
Clay Creek	9	0	2.7	10.6	0	0.2	0.1	0.1
Windy Creek	8	0	5.4	8.0	0	0	0.5	0
Upper Fox River	3	0	0.3	1.7	0	0	0.7	0

TABLE 7.—Catch per unit effort (number of fish per trap night) of coho salmon juveniles in minnow traps at the lower Fox River primary sampling site, Alaska, 1985-1986.

Sample period	1985			1986		
	Number of traps	Mean number of fish	SD	Number of traps	Mean number of fish	SD
6/1 - 6/7	3	0		6	0	
6/19 - 6/25	1	0		3	0.3	0.6
7/10 - 7/17	4	1.0	0.8	5	0.2	0.4
7/26 - 7/28	4	0		4	0	
8/15 - 8/22	3	0		1	4.0	0
8/27 - 9/04	1	1.0	0	0	-	-
9/06 - 9/09	4	0	0	4	1.0	2.0
9/17 - 9/20	7	24.7	60.1	6	1.2	1.3
9/25	0	-	-	8	2.9	2.6
10/1 - 10/3	6	1.2	1.2	4	1.0	1.4
10/22	0	-	-	6	3.2	5.0
10/29	0	-	-	8	3.5	4.3

Overall, Dolly Varden were the most abundant fish species surveyed by visual methods, with peak counts (Clearwater Slough and Clay Creek combined) of 2,370 in 1985 and 1,603 in 1986 (Table 2). Counts were considered highly variable due to the small size and quick movements of this species; therefore, spawning population estimates were not calculated.

Juvenile Dolly Varden were the most commonly captured fish in minnow traps (Table 6) but were seldom caught with beach seines or dip nets (Table 5). Highest catches in minnow traps were observed at Clay and Windy creeks during both years. Average catch rates of juvenile Dolly Varden at these locations exceeded 20 fish per trap night in 1985 and 8 fish per trap night in 1986.

Age determinations were made on otoliths from 101 Dolly Varden collected during 1985 and 1986 (Table 8). Ages ranged from 1 to 8 with the majority of fish (80%) estimated at ages 3, 4, and 5. The average fork length of age 4 fish was nearly 200 mm longer than age 3 fish.

TABLE 8.—Mean fork length and weight at various ages for Dolly Varden collected in the Fox River watershed during 1985 and 1986.

Age	Fork length (mm)				Weight (g)			
	N	Mean	SD	Range	*N*	Mean	SD	Range
1	3	98	9.8	90-109				
2	7	112	6.7	105-125				
3	18	130	8.0	113-142				
4	31	329	19.5	285-360	20	377	70.4	260-490
5	32	368	43.3	315-490	19	538	172.9	325-860
6	6	401	28.7	355-430	5	654	167.3	420-880
7	3	480	40.9	435-515	3	1,205	363.8	830-1,550
8	1	530			1	1,300		

Other Species

Eulachon were found in the lower Fox River below Clearwater Slough from mid-May to late June (Figure 4). Gill net catches during this time period ranged from two to 10 fish per 10-minute drift. No eulachon were observed spawning, but it is presumed that spawning occurred in the lower Fox River because all sampled fish were in spawning condition. The mean fork length for eulachon was 200 mm (*N*=10).

The anadromous form of threespine stickleback was observed in the lower Fox River, Clearwater Slough, and Helicopter Creek, and the resident form occurred in Windy Lake (Table 1). Anadromous threespine stickleback, distinguished from the resident form by an enlarged ventral keel and by their larger size (Morrow 1980), were first seen at Clearwater Slough in mid-June, 1985 and in late May, 1986 (Figure 4). Individuals in spawning condition were observed until late June both years. As anadromous forms were not encountered anywhere else in the system, lower Clearwater Slough appeared to be the primary spawning area for this species.

The catch rate of resident threespine stickleback in minnow traps at Windy Lake during 1985 was several times higher than the catch rate of anadromous threespine stickleback at Clearwater Slough (Table 6). Beach seining in backwater areas of Clearwater Slough, however, occasionally produced large catches of juvenile threespine stickleback (Table 5). One seine haul at Two Bog, a backwater area adjacent to Clearwater Slough, appeared to contain several hundred juveniles, but was not counted due to excessive aquatic vegetation. These juveniles were presumably offspring of anadromous threespine stickleback.

Ninespine stickleback were scarce in the Fox River watershed. They were discovered in very low abundance in Clearwater Slough, the lower Fox River, and Clay Creek (Tables 1 and 6).

Coastrange and slimy sculpin occurred in the Fox River watershed as far upstream as Clay Creek (Table 1). Coastrange sculpin were found in all areas sampled with the exception of Bluff Creek and Windy Lake. The distribution of slimy sculpin was similar to that of coastrange sculpin except it was not collected in Helicopter Creek or the Upper Fox River. The relative abundance of coastrange sculpin was higher than slimy sculpin based on minnow trap catch rates (Table 6).

Sport Fishing Use

Fishermen accessed the Fox River drainage by powerboat, airboat, horseback, and airplane. A primitive airstrip south of the refuge boundary was used by the majority of the people for fly-in fishing trips. Of the anglers interviewed, most were from Homer or the Russian villages, others were from Anchorage, and some were non-resident clients of Homer outfitters.

Thirty-three anglers were interviewed between July 1 and October 3 in 1985. The majority of angling effort was focused toward coho salmon, however, a few anglers fished for sockeye salmon during July, and Dolly Varden were targeted if salmon fishing was slow. Anglers reported catch rates of 0.2-1.1 sockeye salmon and 1.0-4.3 coho salmon per hour. Anglers spent an average of 2.8 hours fishing per day, mostly during evening hours.

In 1986, angler activity was monitored primarily during the coho salmon run. On eleven evenings between August 17 and September 17, an average of 5.3 anglers per day were observed. Most had caught their limit of three coho salmon in 2-3 hours and reported that they were catch-and-release fishing after that. On several occasions, anglers were seen obviously exceeding the legal catch limit for coho salmon. Some anglers interviewed admitted to ignorance of fishing and boating regulations on the refuge.

Physical and Chemical Characteristics

Discharge on the Fox River ranged from 3.3-45.1 m^3/s and averaged 22.3 m^3/s during May-November (Table 9). This level of discharge is nearly ten times that observed on Clearwater Slough, the largest tributary to the Fox River. Average flows observed at Clearwater Slough, Helicopter, and Clay creeks were 2.4, 0.5, and 1.0 m^3/s, respectively.

Water temperatures observed in the major spawning streams ranged from 1°C during November to 13°C in Helicopter Creek during late July. Average water temperatures were lowest in the Fox River and highest in Clay Creek (Table 9).

TABLE 9.—Physical and chemical characteristics of major spawning streams in the Fox River watershed, Alaska, May-November, 1985-1986.

Characteristic	Lower Fox River	Clearwater Slough	Helicopter Creek	Clay Creek
Discharge (m^3/s)				
Mean	22.3[a]	2.4	0.5	1.0
Range	3.3-44.5	1.0-5.0	0.3-0.8	0.5-2.0
Temperature (°C)				
Mean	3.8	6.5	7.7	8.0
Range	1-9	1-11	2-13	2-12
pH				
Mean	7.0	7.0	7.3	7.0
Range	6.9-7.1	6.8-7.2	7.1-7.5	6.9-7.2
Conductivity (µmho)				
Mean	58	85	158	66
Range	16-92	42-138	136-175	29-85
Alkalinity (mg $CaCO_3$/L)				
Mean	21	33	70	26
Range	11-50	16-49	61-75	18-32

[a] Discharge for the Fox River taken from U.S. Army Corps of Engineers data (1982a) and one value measured during this study.

Little variability was observed in pH values observed at the major spawning streams. An average pH of 7.0 was observed at all locations except Helicopter Creek which had a mean pH of 7.3. The lowest pH values in the Fox River watershed were found in bog-stained waters such as Bog Creek and One Bog (Appendix 3).

Helicopter Creek had the highest conductivity and alkalinity values among the major spawning streams in the Fox River watershed (Table 9). Conductivity and alkalinity at Helicopter Creek averaged 158 µmho and 70 mg $CaCO_3$/L, respectively. Conductivity and alkalinity values at other major spawning streams were generally less than half those observed at Helicopter Creek.

Water chemistry and stream discharge data from all waters surveyed are presented in Appendix 3.

Discussion

The assemblage of fish species found in the Fox River watershed is similar to that found in other Kenai Peninsula rivers and streams with two exceptions. First, chum salmon, though common in lower and eastern Kenai Peninsula waters, are not known to occur in eastern Cook Inlet tributaries. Their northernmost known range on the western Kenai Peninsula is the Martin River (Alaska Department of Fish and Game 1983c), and Morsell et al. (1986) found chum salmon spawning in the Bradley River, adjacent to the Fox River mouth. Both systems are tributaries to Kachemak Bay located just south of the Fox River (Figure 2). Hence, occurrence of chum salmon in the Fox River may represent the northernmost extension of chum salmon on the Kenai Peninsula. Second, sockeye salmon are not present in most other Kachemak Bay streams. Populations which have been documented include a small run of 350 fish to the Martin River (U.S. Army Corps of Engineers 1982b), and a run into Fox Creek (Figure 2), which drains Caribou Lake (Alaska Department of Fish and Game 1983c). The next stream north of Kachemak Bay with sockeye salmon is the Kasilof River, and the next one south is the English Bay lake system (Figure 1).

Sockeye Salmon

Sockeye salmon were found in the Fox River watershed as far upstream as Waterfall Creek. This finding extends the distribution of sockeye salmon in the Fox River drainage since, prior to this study, sockeye salmon had been documented only as far upstream as Clearwater Slough (Alaska Department of Fish and Game 1983c). This lake-oriented species was expected to occur in Windy Lake, but no adults or juveniles were captured.

Sockeye salmon were observed in the Fox River drainage from late June through late August-early September each year with most spawning occurring during late July and early August. This run timing corresponds with general salmon run timing information for the Southern District of the Lower Cook Inlet management area (Alaska Department of Fish and Game 1977).

Spawning escapements of sockeye salmon in Clearwater Slough and Clay Creek were estimated between 1,000 and 1,100 fish in each stream during 1986 using the "Factor 5" method. These estimates were higher than aerial estimates of escapement obtained by the Alaska Department of Fish and Game (1985a) during other years. Aerial counts in 1976, 1982, 1983, and 1985 resulted in escapement estimates of 600, 1,060, 600, and 200 fish, respectively. Although sockeye salmon were the second most abundant salmon species in the Fox River, they are of minor importance in terms of number of fish harvested commercially in the Southern District of the Lower Cook Inlet management area (Alaska Department of Fish and Game 1984).

The "Factor 5" method may have introduced varying degrees of bias in estimating escapement of sockeye and other salmon species. The number

of surveys used to obtain M (average of live counts) was small in this study, ranging from two to five surveys for each species. Additional surveys would have yielded more reliable estimates, but were not within the scope of this investigation. In addition, average redd life of salmon can vary in different locations. It is possible that the values used in this study did not accurately represent redd life for Fox River salmon, thereby introducing some bias.

In 1985, juvenile sockeye salmon captured in beach seines and dip nets were larger than those collected in 1986. The discrepancy in mean lengths between years was most likely due to differences in sample dates between years. In 1985, lengths of juvenile sockeye salmon were measured during August and September, whereas in 1986 many lengths were measured on fish collected during late May and June.

Pink Salmon

The distribution of pink salmon in the Fox River extended only as far upstream as Clearwater Slough. This was considered typical as pink salmon spawning distributions rarely extend as far upstream as other salmon (Bailey 1966). On two occasions, pink salmon tagged in the Bradley Lake study (Morsell et al. 1986) were observed in Helicopter Creek. These fish were originally tagged about 5 km up the Bradley River, had returned to Cook Inlet, and then entered the Fox River on the way to spawning grounds in Helicopter Creek. Pink salmon exhibit the greatest degree of straying behavior among species of Pacific salmon (Morrow 1980).

Pink salmon were observed at Clearwater Slough in July and remained until late August both years. Abundance of pink salmon, the principal salmon species in the Bradley River, peaked between August 12 and 14, 1986 (Morsell et al. 1986). Spawning was observed at Helicopter Creek and upper Clearwater Slough only in late July, which corresponds to general run timing information for the Southern District of the Lower Cook Inlet management area (Alaska Department of Fish and Game 1977). Pink salmon have a well-defined spawning period (Sheridan 1962).

Peak spawning counts of 200 fish in 1985 and 35 fish in 1986 indicated that the small pink salmon run in the Fox River was stronger in odd-numbered years than in even-numbered years. This is opposite of the even-year annual spawning pattern in most upper Kenai Peninsula rivers (Alaska Department of Fish and Game 1982b), but in accord with the historical odd-year runs characteristic of Kachemak Bay (Alaska Department of Fish and Game 1978). Peak counts were considered representative of total abundance, due to the reliability of this method in estimating abundance of a species which spawns over a short period of time (Cousens et al. 1982).

Efforts to collect outmigrating juvenile pink salmon during late May in 1986 were unsuccessful. Fry outmigration in other lower Kenai Peninsula waters occurs primarily during April and early May (Ted McHenry and Tom Schroeder, Alaska Department of Fish and Game, personal

communication). Therefore, fry sampling in this study was probably conducted after outmigration had occurred.

Chum Salmon

Chum salmon were first observed at Clearwater Slough in early July and remained in the system until late August both years. This run timing corresponds with streams in Lower Cook Inlet (Alaska Department of Fish and Game 1977) and the timing of the chum salmon run in the Bradley River (Morsell et al. 1986). The majority of chum salmon, including all those radio tagged, spawned in groundwater-fed Helicopter Creek. The presence of groundwater upwelling appears to be a key factor influencing spawning habitat selected by chum salmon (Hale 1981).

An escapement estimate of 325 chum salmon in Clearwater Slough during 1986 is comparable to numbers of chum salmon spawning in the Bradley River. Morsell et al. (1986) estimated between 250 and 500 chum salmon in the Bradley River during 1986.

Of the two age groups observed, age 0.3 chum salmon were slightly larger than age 0.4. This anomalous result was probably due to small sample sizes for age 0.4 fish.

No chum salmon fry were captured during late May in 1986 indicating earlier outmigration similar to that indicated for pink salmon.

Chinook Salmon

Six chinook salmon in spawning condition were observed in Clearwater Slough and Helicopter Creek during mid-August. Similarly, 30 chinook salmon in spawning condition were captured in the Bradley River during August in 1986 (Morsell et al. 1986). The origin of chinook salmon observed in the Fox and Bradley rivers is unknown. If the runs are naturally occurring, they are the only documented late runs of chinook salmon in Kachemak Bay (Alaska Department of Fish and Game 1983c). If the fish observed were strays, the August timing of the runs was several weeks later than timing of other known runs in the area.

Coho Salmon

Coho salmon occurred in every major clear water tributary in the Fox River watershed and were the only salmon species which spawned in the mainstem Fox River. Cousens et al. (1982) reported that coho salmon will use highly turbid waters for spawning, usually delaying actual spawning until decreasing temperatures have reduced the flow and sediment load. This appears to be the case with Fox River spawners, as indicated by late upstream movement of radio-tagged fish from Clearwater Slough. The Alaska Department of Fish and Game (1983a) also found that many coho salmon hold over in Clearwater Slough and spawn in upstream tributaries or in the mainstem Fox River after glacial water subsides following freeze-up.

The temporal and spatial distribution patterns of coho salmon in the Fox River may have biased spawning population estimates obtained for Clearwater Slough and Clay Creek. The spawning period for coho salmon and the average of live counts through the spawning period were probably underestimated due to our inability to count actively spawning adults under the ice late in the season. In addition, radiotelemetry observations indicated that of the coho salmon tagged at Clearwater Slough, 33% in 1985 and 17% in 1986 spawned in the mainstem Fox River. If these percentages paralleled the proportion of the untagged mainstem spawners which stopped at Clearwater Slough before moving upstream to spawn, we may have overestimated the spawning escapement in Clearwater Slough.

Catches of juvenile coho salmon in the lower Fox River steadily increased during late summer and fall in 1986 when the Fox River began to clear. Turbidity can strongly influence fish distribution and studies on the Susitna River in Upper Cook Inlet indicate that rearing coho salmon avoid turbid water (Alaska Department of Fish and Game 1983b). This could explain why Fox River catches were so low during the summer months when the glacier was melting and turbidity was high. As air temperatures decreased in late summer and fall, glacier melt slowed, the Fox River cleared, and tributary stream flow decreased. As clear water habitat decreased in tributaries (due to lower flow) and increased in the Fox River, coho salmon juveniles rearing in tributaries may have moved into this newly available habitat.

Sport Fishing Use

The abundance of fish and wildlife in the Fox River watershed attracts anglers, hunters, and other outdoor enthusiasts. Although used primarily by local villagers in the past, the area has gained the popularity of outsiders due to better means of access and development activities at nearby Bradley Lake. The remoteness and isolation have aided and abetted the likelihood of illegal fishing and hunting. Increased use without vigilant law enforcement could have adverse impacts on resources in the drainage.

Physical and Chemical Characteristics

The physical and chemical characteristics of the Fox River can be compared with other glacial systems entering Kachemak Bay. Discharges on the Fox River range from 3.3-45.1 m^3/s, and average 22.3 m^3/s during May-November. Discharges on the Bradley River range between 3.3 and 57.6 m^3/s and on Sheep Creek between 2.4 and 75.3 m^3/s for that time period. Discharges from smaller systems such as the Martin River range from 0.9-23.5 m^3/s and from Battle Creek between 1.0-13.4 m^3/s from May-November (U.S. Army Corps of Engineers 1982b).

Peak water temperatures in the Fox River between May and November, 1985-1986, were higher than observed during 1979 in the Bradley River (range: 0.2-6.3°C) and Sheep Creek (range: 2.2-3.6°C). The pH range for the Fox River, at 6.9-7.1, was lower than the Bradley River (7.4-8.2)

and Sheep Creek (7.8-8.3) for the same time periods (U.S. Army Corps of Engineers 1982b).

Recommendations

In view of the observed disregard for fishing and hunting regulations in the refuge portion of the Fox River watershed, better law enforcement is recommended. Supercub airplanes used frequently by visitors to access the area indicate their suitability for use by refuge enforcement staff to spot-check fishing activities.

It is strongly recommended that information signs be installed where the refuge boundary crosses the Fox River. The signs should clearly display the refuge boundary and current bag limits, fishing and hunting regulations, boat requirements, and other pertinent regulations or limitations. Other strategic locations for such information would be at the unimproved airstrip, the mouth of Clearwater Slough, the East End Road trail head, the Russian Villages, and Homer harbor.

Acknowledgements

Special acknowledgements are extended to seasonal biologist Jeff Booth, who was invaluable during fieldwork. Gerry Gray, Dave Faurot, Ray Jones, Judd Munroe, and Gary Sonnevil critically reviewed the report. Other biologists, seasonal employees, and volunteers who collected field data include: Jack Dean, Jim Friedersdorff, Becky Everett, Dave Beedle, Mark Veloske, Agnes Rollins, Alan Sisson, Mark Dean, Betty Dean, Ellen Simpson, and Vicki Saab. Retired project leader Jack Dean deserves special thanks for formulating and outlining the study and completing all pre-study preparations.

Technical assistance and piloting for radiotelemetry flights were provided by Bill Larned and Bob Ritchey (Kenai National Wildlife Refuge) in refuge aircraft. Radiotelemetry receivers were provided by the Kenai National Wildlife Refuge and Carl Burger (U.S. Fish and Wildlife Service, Anchorage, Alaska).

References

Alaska Department of Fish and Game. 1971. Population studies of anadromous fish populations - southwestern Kenai Peninsula. Division of Sport Fisheries, Report Number G-11-C, Homer, Alaska.

Alaska Department of Fish and Game. 1977. A fish and wildlife resource inventory of the Cook Inlet-Kodiak areas. Volume 2: Fisheries. Juneau, Alaska.

Alaska Department of Fish and Game. 1978. Alaska's fisheries atlas. Volume 2. Juneau, Alaska.

Alaska Department of Fish and Game. 1982a. 1982 Kachemak Bay subsistence gillnet fishery. Division of Commercial Fisheries, Lower Cook Inlet Data Report Number 83-1, Homer, Alaska.

Alaska Department of Fish and Game. 1982b. 1981 Annual finfish management report. Lower Cook Inlet Data Report. Division of Commercial Fisheries, Homer, Alaska.

Alaska Department of Fish and Game. 1983a. Lower Cook Inlet Data Report 83-1. Division of Commercial Fisheries, Homer, Alaska.

Alaska Department of Fish and Game. 1983b. Susitna Hydro aquatic studies II report; synopsis of the 1982 aquatic studies and analysis of fish and habitat relationships. Anchorage, Alaska.

Alaska Department of Fish and Game. 1983c. Anadromous waters catalog. Habitat Division, Juneau, Alaska.

Alaska Department of Fish and Game. 1984. Lower Cook Inlet salmon fishery - 1984. Division of Commercial Fisheries, Lower Cook Inlet Data Report Number 84-85, Homer, Alaska.

Alaska Department of Fish and Game. 1985a. Aerial counts of Southern District, Lower Cook Inlet area - Clearwater Slough and Fox River tributaries. Unpublished report. Division of Commercial Fisheries, Homer, Alaska.

Alaska Department of Fish and Game. 1985b. Lower Cook Inlet Data Report Number 85-16. Division of Commercial Fisheries, Homer, AK.

Bailey, J.E. 1966. Effects of salinity on intertidal pink salmon survival. Pages 12-15 *in* Proceedings of the 1966 Northeast Pacific Pink Salmon Workshop. Alaska Department of Fish and Game, Juneau, Alaska.

Crone, R.A., and C.E. Bond. 1976. Life history of coho salmon, *Oncorhynchus kisutch*, in Sashin Creek, Southeastern Alaska. Fishery Bulletin 74:897-923.

Cousens, N.B.F., G.A. Thomas, C.G. Swann, and M.C. Healey. 1982. A review of salmon escapement estimation techniques. Canadian Technical Report of Fisheries and Aquatic Sciences Number 1108, Nanaimo, British Columbia.

Federal Energy Regulatory Commission. 1985. Final supplemental environmental impact statement, Bradley Lake Hydroelectric Project. Project Number 8221, Anchorage, Alaska.

Hale, S.S. 1981. Freshwater habitat relationships: chum salmon (*Oncorhynchus keta*). Alaska Department of Fish and Game, Division of Habitat, Resource Assessment Branch, Anchorage, Alaska.

Hartman, W.L. 1959. Red salmon spawning behavior. Pages 48-49 *in* Proceedings of the Ninth Alaskan Science Conference. Bureau of Sport Fisheries and Wildlife, Seattle, Washington.

Heiser, D.W. 1966. Age and growth of anadromous Dolly Varden char *Salvelinus malma* (Walbaum) in Eva Creek, Baranof Island, Southeastern Alaska. Alaska Department of Fish and Game, Research Report Number 5, Juneau, Alaska.

Jearld, A., Jr. 1983. Age determination. Pages 301-324 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries Techniques, American Fisheries Society, Bethesda, Maryland.

Koo, T. 1962. Age designation in salmon. Pages 37-48 *in* S.Y. Koo, editor. Studies of Alaska red salmon. University of Washington Press, Seattle, Washington.

Mattson, C.R., and R.G. Rowland. 1963. Chum salmon studies at Traitors Cove Field Station, June 1960 to March 1963. U.S. Fish and Wildlife Service, Bureau of Commercial Fish, Manuscript Report 1963-11, Auke Bay, Alaska.

Morsell, J., D. Erickson, A. DeToni, and M. Pearsall. 1986. Bradley River salmon escapement monitoring study, 1986. Final report to Alaska Power Authority, Anchorage, Alaska.

Morrow, J.E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Company, Anchorage, Alaska.

Sheridan, W.L. 1962. Relation of stream temperatures to timing of pink salmon escapements in southeast Alaska. Pages 87-102 *in* H.R. McMillan, editor. Lectures in Fisheries, symposium on pink salmon. University of British Columbia.

U.S. Army Corps of Engineers. 1982a. Bradley Lake Hydroelectric Project, Alaska. Final environmental impact statement. Alaska District, Anchorage, Alaska.

U.S. Army Corps of Engineers. 1982b. Bradley Lake Hydroelectric Project, Alaska. Environmental Impact Statement Appendixes. Alaska District, Anchorage, Alaska.

U.S. Fish and Wildlife Service. 1985. Kenai National Wildlife Refuge final comprehensive conservation plan, environmental impact statement, and wilderness review. Anchorage, Alaska.

Wedemeyer, G. 1970. Stress of anesthesia with M.S. 222 and benzocaine in rainbow trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 27: 909-914.

APPENDIX 1.—Dimensions and mesh sizes of gear used in the Fox River watershed survey, Alaska, 1985-1986.

Gear and type	Length (m)	Depth (m)	Mesh (cm)
Gill net			
Floating experimental	12.2	1.8	2.5, 5.1, 7.6, 10.2
Floating experimental	30.5	3.0	2.5, 5.1, 6.4, 7.6, 10.2
Floating experimental	15.2	3.0	1.0, 1.3, 1.6, 1.9, 2.5
Sinking experimental	30.5	3.0	2.5, 5.1, 6.4, 7.6, 10.2
Eulachon	6.1	1.8	5.1
Beach seine	12.2	1.8	0.5
Dip net	-	-	0.6
Minnow traps	0.4	0.3	0.3
Smolt net, conical	2.7	0.5	0.3

APPENDIX 2.— Specifications of radio transmitters used in the Fox River watershed survey, Alaska, 1985-1986.

Specification	1985	1986	
	All salmon	Coho	Dolly Varden
Frequency (mHz)	167-168	40-42	40-42
Battery size	1/2 A	2/3 A	1/2 A
Transmitter length (mm)	23.0	33.5	23.0
Transmitter weight (g)	25	35	23
Timer	2 stage	2 stage	2 stage
Pulse rate (pulse/min)	50-60	50-60	50-60
Life (days)	90	140-200	80-120
Battery type	lithium	lithium	lithium

APPENDIX 3.—Stream discharge and water chemistry data from rivers, streams and lakes in the Fox River watershed, Alaska, 1985-1986.

Location	Date	Discharge (m^3/s)	Temp (°C)	pH	Conductivity (μmho)	Alkalinity (mg $CaCO_3$/L)
			1985			
Lower Fox River[a]	5/20		5	6.9	78	19
	6/18		8		64	32
	7/18		5		50	16
	8/2		4			
	8/15		4	7.0		17
	8/29		4	6.9		
	11/6		1	6.9	110	50
Lower Clearwater Slough[b]	5/21	1.8	5	7.2	117	45
	5/31	1.4	5		115	49
	6/18	2.9	7	7.0	71	32
	7/10	5.0	9	7.0	60	22
	7/24	1.6	11	7.0	65	28
	8/15		6	6.8		16
	8/29		7	7.0		
	9/6	2.0	6	7.1	98	39
	9/20	2.2	7	7.1	100	37
	10/2	3.1	6	7.0	89	23
	11/6		1	7.2	138	45
Upper Clearwater Slough[c]	5/3		1	6.9	87	27
	8/2		9	6.9	58	24
Clearwater Lake Fork	5/3		2	6.9	129	48
Cache Creek	6/18	0.1		7.5	188	91
	7/18		8		195	89
	7/24		13	7.4	200	152
	8/15		8	7.5	213	92
Helicopter Creek	5/3		5	7.2	147	65
	6/18		4			
	6/26	0.6	5	7.3		
	7/10		9	7.3	163	71
	7/16	0.5	11			
	7/24		13	7.2	136	58
	8/1	0.5	11			
	8/15		7	7.3	175	138
	8/29		8	7.5		
	9/5	0.5	8	7.4	169	74
	10/2	0.6	7	7.4	173	70

APPENDIX 3.—(Continued)

Location	Date	Discharge (m^3/s)	Temp (°C)	pH	Conductivity (µmho)	Alkalinity (mg $CaCO_3/L$)
Surprise Creek	10/2		2	7.2	156	54
Two Log Creek	7/11		10	6.8		
Bluff Creek	7/10	1.3	6	7.1	38	16
Bog Creek	7/10		11	6.4	103	43
Windy Creek	8/23		5	6.9	53	20
	9/11	0.9	5	6.8	70	20
Clay Creek	8/23	1.4	2	6.9	64	20
	9/11	2.1	5	7.1	82	30
	9/20	0.9	5	7.0	76	27
Fry Creek	8/23		2	6.9	99	31
Waterfall Creek	8/23		5	6.9	66	21
Windy Lake	7/26		16	7.2	55	20
	8/19		13	7.1	64	20
			1986			
Upper Fox River[d]	7/14		8	6.9	39	18
	8/14		5	6.9	23	14
	10/8		3	7.0	63	15
Lower Fox River[a]	5/28		5	6.9	71	21
	6/25		3	7.1	54	18
	7/22		6	6.9	50	20
	7/29		3	7.0	39	18
	8/13		5	6.9	22	13
	8/21		9	7.1	18	12
	8/28		3	6.9	61	
	9/5		2	6.9	44	11
	9/11		2	7.0	44	14
	9/20		2	7.0	40	18
	9/25		1	6.9	56	21
	10/3		4	7.0	51	18
	10/22		2	7.0	74	21
	10/29		1	6.9	91	24
	11/17	3.3	1		92	31

APPENDIX 3.—(Continued)

Location	Date	Discharge (m^3/s)	Temp (°C)	pH	Conductivity (μmho)	Alkalinity (mg $CaCO_3$/L)
Lower Clearwater Slough[b]	5/28	2.7	8	7.0	70	24
	6/24	2.3	7	7.0	77	31
	7/8	3.6	8	7.1	61	23
	7/29		9	7.1	90	38
	8/6	2.3	8	6.9	63	27
	8/12	2.7	8	7.0	42	29
	8/20	1.6	10	7.0	42	35
	8/28		8	6.9	55	22
	9/4	3.4	9	7.0	88	32
	9/10	3.6	7	7.0	80	32
	9/18		6	7.0	74	27
	9/24	1.7	3	6.9	97	42
	10/1	1.3	7	7.0	100	43
	10/21	2.6		7.0	98	39
	10/29	1.2	1	6.9	115	39
	11/17	1.0	2	7.0	117	38
Upper Clearwater Slough[c]	5/28		8	7.1	50	14
	6/25		6	7.0	50	12
	7/9		6	7.0	45	13
	8/5		7	7.1	35	10
	8/20	1.0	6	7.2	49	15
	9/23		4	7.1	55	7
Clearwater Lake Fork	5/29		14	6.8	81	26
	6/25		14	6.9	77	30
Clearwater Lake	10/3		10	7.3	80	36
One Bog	7/8		14	6.3	123	42
Cache Creek	8/28	0.2	8	7.6	199	87
Helicopter Creek	5/28	0.5	9	7.3	162	69
	6/24	0.5	7	7.4	164	70
	7/8	0.5	10	7.4	160	70
	7/28	0.8	11	7.5	163	68
	8/6	0.5	7	7.2	161	70
	8/12	0.5	8	7.4		70
	8/20	0.5	12	7.3	166	65
	8/27	0.3	7	7.3	166	61
	9/4	0.8	8	7.3	166	72
	9/10	0.8	9	7.3	160	75
	9/18	0.8	7	7.3	159	75
	9/23	0.5	8	7.3	162	72

APPENDIX 3.—(Continued)

Location	Date	Discharge (m^3/s)	Temp (°C)	pH	Conductivity (μmho)	Alkalinity (mg $CaCO_3$/L)
	10/1	0.3	6	7.2	163	75
	10/21	0.5	6	7.3	162	68
	10/29	0.4	2	7.1	167	72
	11/17	0.5	3	7.4	162	72
Two Bog	7/10		16	6.9	127	58
	8/5		17	7.0	92	40
Bluff Creek	6/26		7	7.0	56	19
	7/9		8	7.0	64	24
	8/5	0.2	11	7.1	77	32
	8/22	0.2	10	7.2	42	27
High Lake	7/11		16	7.3	65	29
Windy Creek	7/15	0.1	8	7.0	66	35
	7/22		11	6.9	69	32
	8/14	0.1	8	6.9	65	37
	9/26		5	7.0	52	21
	10/8	0.2	5	7.1	67	24
Clay Creek	7/11	1.2	11	6.9	44	18
	7/14	0.7	12	6.9	61	23
	7/21	2.0	12	7.0	57	28
	8/13	0.5	11	7.2	66	29
	8/27	0.8	9	7.0	29	20
	9/3	0.7	11	6.9	77	24
	9/26	0.5	4	7.0	72	29
	10/3		6	6.9	80	28
	10/8	0.5	9	6.9	85	32

[a] Measurements for lower Fox River taken near confluence with Clearwater Slough.
[b] Measurements for lower Clearwater Slough taken below Helicopter Creek.
[c] Measurements for upper Clearwater Slough taken below the waterfall.
[d] Measurements for Upper Fox River taken near confluence with Clay Creek.